State of California
THE RESOURCES AGENCY
Department of Water Resources

PILOT LEVEE MAINTENANCE STUDY

Preview of Bulletin No. 167

FEBRUARY 1966

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

State of California
THE RESOURCES AGENCY
Department of Water Resources

PILOT LEVEE MAINTENANCE STUDY

Preview of Bulletin No. 167

FEBRUARY 1966

HUGO FISHER	EDMUND G. BROWN	WILLIAM E. WARNE
Administrator	*Governor*	*Director*
The Resources Agency	State of California	Department of Water Resources

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

FIGURES

GLOSSARY

PLATES

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
WILLIAM E. WARNE, Director, Department of Water Resources
ALFRED R. GOLZE', Chief Engineer
JOHN R. TEERINK, Assistant Chief Engineer, Planning & Operations

---

This report was prepared under the direction
of the
Sacramento District

Carl A. Werner . . . . District Director
Robert E. Whiting . . . . Chief, Delta Studies Section
John O. McClurg . . . . Chief, Delta Coordination Unit

Various phases of this investigation were conducted
and this report prepared
by

Larry C. Davis . . . . Program Manager
Philip T. Zwanck . . . . Field Superintendent

Test site preparation was accomplished by personnel
of

Sacramento Maintenance and Repair Unit . Sacramento District

Cooperators providing advice and guidance
on various phases of the investigation
were

Ott Bauer . . . . Department of Fish and Game
Sven G. Anderson . . . . Division of Soil Conservation
Oswald Hoglund . . . . U. S. Soil Conservation Service

Plant performance evaluations were conducted
by

Omer King . . . . Division of Soil Conservation
Clifford Sorensen . . . . . . U. S. Soil Conservation Service

Irrigation and test plot planting and maintenance
was accomplished by personnel
of

Department of Conservation . . Division of Soil Conservation
Department of Conservation . . . . Division of Forestry

FOREWORD

In 1961, the California State Legislature authorized the Sacramento River and Delta Recreation Study. One of the recommendations was that "a program of pilot studies on selected reaches of levee be initiated to test various types of vegetation, determine control measures necessary, study methods for these controls, and determine the costs for this type of maintenance." In response to that legislative recommendation, the Department of Water Resources initiated the Pilot Levee Maintenance Study in 1962. The pilot study is scheduled for a minimum of five years to allow ample time for the growth and evaluation of test plantings.

This Pilot Levee Maintenance Study Report summarizes not only the activities that have taken place to July 1, 1965, but also the work proposed for the remainder of the program, the findings and tentative conclusions drawn from ongoing experiments and observations, and the recommendations made.

The program will terminate June 30, 1967. At that time recommendations will be made regarding specific types, density, and positions of grasses, shrubs, and trees for use on Delta levees, and maintenance practices.

ABSTRACT

Pilot Levee Maintenance Study

The Pilot Levee Maintenance Study in the Sacramento River Delta indicates that techniques can be developed to preserve and enhance the value of Delta levees for recreation and wildlife without interfering with the primary function of flood control. Present levee maintenance practices can be broadened by including a vegetative management program that will benefit flood control as well as recreation and wildlife.

Any growth that prevents annual inspection of the levees is unacceptable. Such growth includes grape and blackberry vines and dense clumps of low-growing shrubs and trees.

With proper encouragement, ground cover can help to control erosion in berm areas and on levee slopes. Where water flows at high velocity at the bank, erosion cannot be controlled by vegetation alone; rock protection is necessary.

Ground cover planted on fill material spread to a depth of 6 inches over cobble rock on a section of berm survived as long as 45 days of continuous inundation during the flood of December 1964 and January 1965. However, none of the ground cover tested recovered after being covered with more than 6 inches of sediment.

Of the ground cover plants tested, the best for both erosion control and survival without summer irrigation were kikuyu grass, coastal bermuda, and creeping wildrye. However, none of the plants tested grew well more than 20 feet above summer water levels (the upper third of the levee slope).

Trees are not detrimental to levee slopes unless they are in danger of toppling over as a result of wind and water action. Trees selected for planting are those that have taproot systems, are resistant to common diseases, have a small canopy and sturdy trunk and limbs, and have a maximum height of 30 to 35 feet.

Trees planted on berm areas survived both the inundation and sediment deposition of the 1964-65 flood. During the summer, most of the young trees in the berm areas thrived, but those on the upper portions of the levee slopes were not doing well.

Cobble rock placed around the bases of trees controlled erosion when the slope was no steeper than 2:1.

Studies will be required following the Pilot Levee Maintenance Study to develop specific proposals for multiple-purpose levee maintenance projects using recommendations for vegetation management.

CHAPTER I - INTRODUCTION

Historically, levees have been constructed and maintained for the single purpose of flood control. However, in spite of accepted maintenance practices, much of the Delta at one time or another has had tree-lined levees. Whether this has come about because of deferred maintenance, local operations on nonproject levees not subject to federal regulations, or lack of regulation enforcement, continuing and strict adherance to existing maintenance practices would spell the doom of the few remaining attractive levees. With the demand for recreational opportunities increasing by leaps and bounds, ways should be found to preserve and, if possible, enhance the recreational value of the Delta.

Recreation and conservation groups, in their determination to save the natural beauty of Delta waterways, have overtly criticized all agencies responsible for the construction, operation, and maintenance of levees. These groups contend that vegetation on levees and berms is essential to preserving the value of the Delta for the many recreational activities on and along Delta channels. Wildlife too depends on whatever vegetation can be found on levees and berms because of the lack of cover to be found within the "clean farmed" interior islands.

Levee maintenance agencies, however, point out that the primary and only authorized function of levees is to control floods. They insist that the least costly and safest way to accomplish this function is to keep levees free of vegetation.

They contend that wild growth prevents proper inspection, jeopardizes levee integrity when trees topple over, and impedes flood fighting activities.

The conflict between advocates of levees with vegetation and advocates of levees without vegetation must be resolved if the needs of both interests are to be met.

Purpose and Scope of Study

The purpose of the Pilot Levee Maintenance Study is to find vegetation and maintenance techniques for levees that can be used to preserve and enhance recreational and aesthetic values of the Delta and, at the same time, will be compatible with the flood control function of levees.

Tests are being made that will lead to recommendations of the type and density of grasses, shrubs, and trees for use on levees and berms. Balanced consideration will be given to the requirements of flood control, recreation, and wildlife. Recommendations will also be made as to how vegetation should be maintained to achieve its full value for flood control, recreation, and wildlife. Final recommendations will be forthcoming at the close of the five-year study. Cost estimates will be made for recommended maintenance techniques. Formulas for sharing of costs and methods for financing are not within the scope of this study but are within the scope of the Resources Agency Delta Recreation Study and will be developed as part of the Delta Recreation Master Plan. This report describes the progress during the first three years and presents a preview of those recommendations.

Undisturbed levee section demonstrating deferred maintenance. Inspection is practically impossible.

Reconstructed levee revetted with rock. Flood control consideration only.

The Pilot Levee Maintenance Study is coordinated through the Resources Agency Committee for Delta Recreation Planning, since development of a Delta Recreation Master Plan will largely depend on solving the levee vegetation problem as it affects flood control, aesthetic beauty, and wildlife population. Cooperating with the Department of Water Resources in the Pilot Levee Maintenance Study are the State Departments of Conservation and Fish and Game. They assist in plant selection for testing, planting, and maintenance procedures, and plant performance evaluations.

Flood control requirements will limit the types and density of vegetation that can be tolerated on levees. From the standpoint of flood control, the principal objectives of levee maintenance are to preserve the stability of levees and maintain the slopes adequately for effective inspection and patrolling and flood fighting activities. These objectives cannot be compromised.

Levees must be inspected to locate rodent burrows, caves, sloughs, or other damages to the structures. Inspection is, of course, essential, and vegetation must not stand in the way of performing this job effectively.

The integrity of the levee can be jeopardized by trees that are in danger of being uprooted by wind or wave action. Fallen trees can also cause adverse current deflections and accumulate drift, both of which compound erosion. In the event of a flood fight, trees can obstruct the placement of canvas, wave wash panels, or sandbags.

Typical example of erosion around trees
endangering levee stability.

Levee vegetation particularly trees, provides an important habitat for significant populations of over 100 wildlife species. Destruction of levee vegetation could mean the eventual elimination of these species from the Delta. Thick, bushy evergreen trees and shrubs are best for most species of wildlife. Several combinations of trees and shrubs are needed to support maximum wildlife numbers.

The scenic beauty of levee vegetation lies not in any particular kind of tree, shrub, or grass, but in the effect a combination of these plants has on the beauty of a waterway -- an effect that furnishes a type of isolation, or escape from everyday realities. Such beauty is generally exemplified by thick underbrush and trees overhanging the waterways. The optimum recreation value depends on scenic beauty.

Many recreation groups require controlled vegetation, especially where their activities depend on the actual use of levees and berms adjacent to the waterway. These groups include water skiers, picnickers, bank fishermen, swimmers, and campers.

The foregoing discussion reveals that the requirements of flood control, recreation, or wildlife taken separately could result in levees varying from barren, rock reveted slopes to overgrown jungles. The compromise required to achieve a balance among the requirements of flood control, wildlife, and recreation obviously will fall someplace between these two extremes.

Area of Investigation

The Pilot Levee Maintenance Study's field testing and observations are confined to the Sacramento-San Joaquin Delta and levees along the Sacramento River.

Three major areas selected for field testing are: (1) Garcia Bend test site on the left bank of the Sacramento River, about 2 miles upstream from the town of Freeport; (2) Ryde test site on the left bank of the Sacramento River about 1 mile downstream from the town of Ryde; and (3) Steamboat Slough test site along both banks of Steamboat Slough, extending from the junction of Steamboat Slough and the Sacramento River for a distance of about 2,500 feet downstream.

Other specific areas along the Sacramento River with varying hydraulic and vegetative conditions have been selected for testing and observation. The locations of all these sites are shown on Plate 1.

CHAPTER II - PURPOSE OF EXPERIMENTATION

Experimentation at the various test sites is designed to provide information on plant adaptability, control of vegetation, levee reconstruction, and aesthetic treatment of rock revetment. The nomenclature commonly used for describing levee structures is shown on Figure 1.

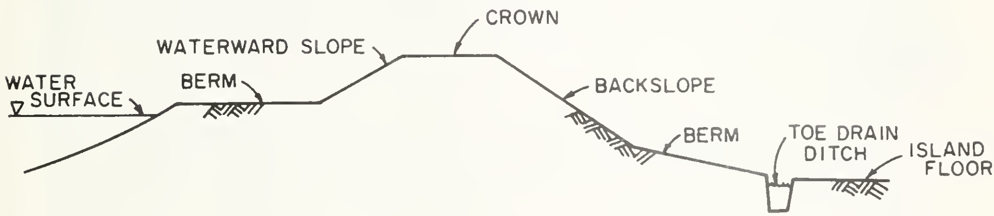


Figure 1 - Nomenclature of a Levee

Plant Adaptation Studies

After the preliminary selection of vegetation for stabilization of levee banks and recreational and wildlife values, they are tested in the field to determine: (1) plant adaptability to the environment, (2) growth characteristics, (3) erosion control capability, and (4) ability to withstand inundation and silt deposition. The selected species are planted in a uniformly prepared area in the field. The test plots range from the top of the primary levee system to the water's edge and are 20 feet wide. This method allows measurement of the plant's performance throughout varying conditions from water's edge to levee crown within its plot as well as comparison with plants in adjacent plots. All plant adaptability tests in the Pilot Levee Maintenance Study are conducted in this manner.

Controlled Growth

Regular maintenance on many levees is practically nil and vegetation flourishes until major repair work is necessary. The levee is then stripped clean of vegetation and repair work begins.

An experiment is under way at such a vegetated area to determine what is involved in a major clearing program, especially its cost, when the cleaning is done on a selective basis; that is, when vegetation which is not jeopardizing levee integrity or preventing proper inspection is retained. After the initial selective clearing, the area is maintained on an annual basis. This provides further knowledge of the costs involved in maintaining a certain quantity and quality of vegetation.

Levee Reconstruction

Levee reconstruction is often necessary at areas where the levee has degenerated to an unsafe condition. Major erosion results during low water levels when levee banks are susceptible to the erosive action of the channel, wave wash, and boat wakes for long periods of time. Common practice is to clear the existing vegetation, reslope the critical section, and place rock revetment on the waterward slope.

Through coordinated efforts of the Department of Water Resources the Resources Agency Committee for Delta Recreation Planning, and the State Reclamation Board, a test has been authorized by the Corps of Engineers that involves construction of a berm in front of a levee section slated for repair. The berm will consist of dredged material from the channel faced with rock revetment. Construction of the berm to an elevation just above low water will allow the retention of existing vegetation as well as rehabilitation of the section to safe standards. Results of the Corps' experiment will be reflected in the findings and recommendations of the Pilot Levee Maintenance Study.

Aesthetic Treatment of Revetment

The question of what can be done to "dress up" rock revetment is being explored at three locations.

First, a test involving placement of cobble rock around existing trees was undertaken to determine the ability of the rock to remain in place while providing bank protection.

Tests involving placement of soil on existing rock revetment and planting with several species of grasses were tried at two locations.

A special "waffle" block was fabricated and is being tested for its ability to control erosion while encouraging vegetation to grow through its voids. This is being tried as a possible substitute to the quarry rock or cobble rock normally used for bank protection. This combination of mechanical-vegetative toe protection could increase the attractiveness of levee slopes where revetment is needed.

Observation Program

Several locations along the Sacramento River have been selected for observation. These locations have varying vegetative and hydraulic conditions and are photographed periodically so that any physical changes can be documented. This may serve to define better the effects currents, floods, and wave wash have on vegetated levees, especially where trees are growing on levee slopes.

CHAPTER III - PROGRAM ACTIVITIES

The Pilot Levee Maintenance Study began its fourth year starting July 1, 1965. The activities reported herein include the work accomplished to July 1, 1965, and work planned for the 1965-66 fiscal year. Field testing will be completed in the summer of 1966 with evaluations terminating around the beginning of 1967.

Garcia Bend Test Site

The Garcia Bend test site has been used for four separate experiments. The last field installation was completed in September 1964. Observations and experiment evaluations have been under way since July 1963 and will continue until early 1967, as previously indicated.

Aesthetic Treatment of Revetment

At the upstream end of the Garcia Bend test site, a 300 foot waterside section of berm was cleared of all vegetation, resloped to 2:1, then reveted with cobble rock in June 1963. Then in June 1964, 250 tons of fill material were spread to a depth of 6 inches over the cobble and planted in three separate plots with kikuyu grass, coastal bermuda, and creeping wildrye. These plantings were irrigated periodically throughout the remainder of the summer in 1964. Other than rainfall, these plantings have not received any water in 1965. All test plantings were irrigated only through the initial year of establishment. One of the important considerations for all plants will be the ability to survive the summer without irrigation.

Placement of Revetment Around Trees

An area at the Garcia Bend test site on the waterward slope of the berm about 200 feet long containing several trees was selectively cleared, resloped, and reveted with cobble rock in July 1963. Most of the sloping and rocking was done by hand, as the remaining trees prevented the use of equipment normally used for such work. The purposes of this experiment are to determine the cost and practicability of placing revetment around trees and to compare the success of such a method with other means of bank protection.

Erosion Control with Vegetation

Two areas at the Garcia Bend test site on the waterward slope of the berm, each 250 feet long and approximately 50 feet wide, were cleared and planted in kikuyu grass in July 1963. The purpose here is to determine the ability of the planting to survive silt deposition and inundation, while controlling erosion on the berm.

Plant Adaptation Study

The plant adaptation series at Garcia Bend included a spring planting (April 1964) of 5 species and a fall planting (September 1964) of 7 species. The species planted were:

Spring	Fall
Periwinkle	Western wheatgrass
Coastal bermuda	Goars fescue
Creeping wildrye	Topar wheatgrass
Kikuyu grass	Reed canary grass
Alkali bulrush	Perlagrass
	Salina clover
	Los Banos trefoil

Ryde Test Site

The Ryde test site has three separate experiments under way. As with Garcia Bend, observation and evaluations will continue until the early part of 1967.

Plant Adaptation Study

The plant adaptation series at the Ryde test site includes a fall planting (September 1964) of 9 species and a spring planting (May 1965) of 15 species. The species planted were:

Fall	Spring
Alkar wheatgrass	Periwinkle
Greenar wheatgrass	Coastal bermuda
Western wheatgrass	Creeping wildrye
Topar wheatgrass	Kikuyu grass
Goars fescue	Alkali bulrush
Reed canary grass	Pygmy bamboo
Perlagrass	Tifway bermuda (sod)
Salina clover	Tifway bermuda (stolens)
Los Banos trefoil	Tifgreen bermuda (sod)
	Tifgreen bermuda (stolens)
	Broadfruited bur reed
	Saltgrass
	Matgrass
	Aarons beard
	Spikerush

Tree Planting

A tree adaptation test was begun at the Ryde site in June 1964. Ten species of trees were planted. They were:

Red iron bark	Athel
Water wattle	Trident maple
Beefwood	Arizona ash
Common olive	Black mulberry
Hollyleaf cherry	Purple plum

The trees were selected for testing on the basis of their growth characteristics. From the flood control standpoint, many of the trees found along the Delta channels are unsuitable for levee slopes. Therefore, the test trees selected were required to have the following characteristics:

1. Tap-root system as opposed to a spreading root system.
2. Nonsusceptibility to common diseases.
3. Small canopy as opposed to trees that commonly topple from windthrow.
4. Maximum height of 30-35 feet.
5. Sturdy trunk and limbs.

Experimental Bank Slope Protection

A new type of concrete block revetment was installed at the Ryde site on the berm in the plant adaptation area. Each block is 24 x 16 x 4 inches and has eight 3 x 6 inch voids. The purpose of this experiment is to test a method for achieving a combination mechanical-vegetative protection of slopes that are continually subjected to erosion by current and wave action created by wind and boats. The blocks will allow vegetation to grow in the voids.

In the test at Ryde the berm was resloped to 3:1 and the blocks were placed in a continuous mat on the slope from the top of the berm to below low summer water levels. The different test plantings were then extended into the voids of the blocks. The reveted area is within the tidal fluctuation zone at normal summer water levels.

Steamboat Slough Test Site

Two experiments are under way at the Steamboat Slough test site, one of which will be initiated by the Corps of Engineers under the Sacramento River Bank Protection Project.

Controlled Growth

A 2,000 foot section of levee and berm on the left bank of the Steamboat Slough site was singled out for a controlled growth maintenance area in 1964. This area had not been cleared for some time and was overgrown. For some recreation activities, this area offered an ideal environment. However, from the flood control standpoint, the integrity of the levee was endangered by trees on the verge of toppling and inspection was practically impossible in places because of dense undergrowth.

To initiate the controlled growth area, the reach was selectively cleared by removing dead, diseased, leaning, and root-exposed trees and dense undergrowth, such as grape and blackberry vines and dense clumps of low-growing shrubs and trees. This operation increased the integrity of the section and also opened the area for inspection. At the same time, selected vegetation was retained for wildlife and recreation.

The area is now subjected to an annual maintenance program so that a level of vegetation better suited to flood control can be retained at all times.

Berm Construction

This experiment involves construction of a berm in front of a critically eroded section of levee on the right bank of Steamboat Slough. During July 1965, the Corps of Engineers will construct a 400-foot-long berm at one of their bank protection sites. The eroded section of levee has not been cleared for some time, and the objective of the experiment is to see, if by construction of such a berm, this section of levee can be rehabilitated to safe flood control standards without removing the trees on the levee slope. The berm will be constructed from the waterside and will rise about three feet above average summer water levels (an elevation of about 9.0 feet above sea level, Corps of Engineers datum). It will have a quarry rock facing and will be about 10 feet wide at the top.

Sacramento River Observation Stations

Ten observation stations have been selected along the Sacramento River. The stations display varying vegetative and hydraulic conditions and are being photographed at least once a year. A pictorial record of these stations over a period of time will help in determining better the effects of vegetation, especially trees, on levee slopes.

Hood Test Site

A 400-foot-long section of quarry rock on the right bank of the Sacramento River opposite the town of Hood was covered to a depth of 12 inches with material dredged from the channel, planted with four different mixtures of grasses, and fertilized with 16-9-0 at a rate of 300 pounds per acre in mid October 1964. The four mixtures of grasses were:

No. 1	No. 2
2 lbs alfalfa	26 lbs Merced ryegrass
10 lbs annual ryegrass	5 lbs Alta fescue
2 lbs white sweet clover	2 lbs white sweet clover
1 lb narrow-leaf trefoil	2 lbs alfalfa

No. 3	No. 4
10 lbs filaree	40 lbs barley
15 lbs perennial ryegrass	15 lbs Lana vetch
1 lb narrow-leaf trefoil	3 lbs Blando brome
	15 lbs perennial veldt grass

After seeding, mulch (straw) was placed over the area and held in place with erosion net. The area was irrigated about three times a week until the first fall rains. This experiment was a cooperative effort between the U. S. Corps of Engineers and the State Departments of Conservation and Water Resources.

Proposed Work for 1965-66

The work program for 1965-66 will be primarily continued observation of the ongoing tests and installation of additional experiments at a new test site. The new test site will be used for further testing of concepts and plant species that have indicated positive results in initial tests.

Garcia Bend Test Site

No further field work is planned for this test site. Observations and plant evaluations will continue.

Ryde Test Site

No further field work is planned for this test site. Observations and plant evaluations will continue.

Steamboat Slough Test Site

The controlled growth maintenance area will undergo continual maintenance to retain a more suitable level of vegetation for flood control.

The vegetation retained at the Corps of Engineer's test berm site will be maintained in an annual program. Here again, a level of vegetation compatible with flood control requirements will require a rigorous and continuous program.

Sacramento River Observation Stations

These areas will continue to be photographed annually to provide a pictorial documentation of any incremental changes.

Isleton Test Site

A new test site has been selected on the left bank of the Sacramento River about two miles north of the town of Isleton. This site exhibits a varying range of hydraulic, levee, and vegetative conditions. The final phase of field testing for the program will be done in this area.

Specific work planned for the site includes selective clearing of existing vegetation, a shrub adaptation test, revetment at erosion spots, ground cover planting for erosion control where existing cover is insufficient, and tree trimming.

The proposed work for 1965-66 will be based on the preliminary findings of the study at the time this test is undertaken. To the degree possible, the area will represent the desired type and density of vegetation on levees and berms based on preliminary indications of a suitable balance among the requirements of flood control, recreation, and wildlife.

CHAPTER IV - PHYSICAL DATA AND EXPERIMENT COSTS

The flood beginning the latter part of December, 1964 provided valuable information regarding the ability of the test plantings to survive prolonged periods of inundation and deposition.

A detailed accounting of experiment costs is kept to assist in developing cost estimates for any recommended new maintenance practices that result from the study.

Inundation

At Garcia Bend, the Sacramento River began to rise on December 23, 1964 and peaked about 8 feet above the berm at the adaptation series plot on December 27. The river receded gradually and 42 days later was back to its preflood elevation. All test plants that were not covered by deposits of sediment survived at least 30 days of continuous inundation. Since the berms were covered with sediment deposits, it could not be determined if all plants would have survived a longer period of inundation. However, places were found where the coastal bermuda, kikuyu grass, and creeping wildrye came through about 45 days of continuous inundation.

At Ryde the berm area was inundated for about 35 days. Here again, all test plants that were not covered with sediment survived. The trees adjacent to the test plots appeared to have survived equally well.

Deposition

Considerable sand and silt was deposited on both the Ryde and Garcia Bend berm areas. The deposition persisted on the flat portions of the berm and was found to be over 2 feet deep at spots. Kikuyu grass, creeping wildrye, and coastal bermuda demonstrated the best ability to come up through the deposition. But even these species could not recover when sediment deposits were deeper than about 6 inches.

Experiment Costs

The following table summarizes field costs to date (July 1965) on each separate experiment. The costs shown are not indicative of costs that could be expected on large operations involving similar types of work.

Experiment	Experimental Field Costs	
	Total Cost	Unit Cost
Garcia Bend		
Plant adaptation study	$ 7,580	$ 0.31/square foot
Erosion control with vegetation	3,385	0.16/square foot
Placement of revetment around trees	9,537	1.51/square foot
Aesthetic treatment of revetment	3,639	0.29/square foot
Ryde		
Plant adaptation study	$ 7,752	$ 0.20/square foot
Tree planting	572	16 /tree
Experimental bank protection	2,300	23 /lineal foot
Steamboat Slough		
Controlled growth	$ 8,008	$ 0.11/square foot
Toe berm	19,500	48 /lineal foot

CHAPTER V - FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

To find alternative levee maintenance techniques that can be used to preserve and enhance the recreational aesthetics and wildlife values of levees, nine tests are being conducted concerning:

1. Vegetative ground cover on waterside levee slopes
2. Vegetative ground cover on berms
3. Trees on levees
4. Trees on berms
5. Fill material and vegetative ground cover over rock revetment on levee slopes
6. Prefabricated "waffle blocks" in conjunction with vegetative ground cover on levee slopes
7. Management of native vegetation
8. Berm construction
9. Erosion control with vegetation

These tests include 33 species of vegetative ground cover and 10 species of trees.

In comparing one type of treatment with another, appraising the overall results of the tests, and adopting new techniques, the following must be considered: plant adaptability, flood control, recreation requirements, wildlife habitat, and physical and economic life. Included under plant adaptability are such factors as climate, soil, availability of water, deposition, inundation, and resistance to disease. Flood control considerations are erosion control, resistance to wind damage, inspection, and flood fighting. Suitability for recreation includes scenic beauty, shade, and density of vegetation. Requirements for a suitable wildlife habitat includes both food and shelter needs.

Findings discussed are based on test results and conditions observed on Delta levees. The physical and economic life of any proposed new techniques is beyond the scope of this study. Conclusions and recommendations reported herein are preliminary, since many of the test plants are less than two years old, and more time is required for final performance evaluations.

Summary of Findings

The following discussion summarizes the findings to date on the experiments conducted at the test sites and observations made in the Delta.

Aesthetic Treatment of Revetment

The most surprising aspect of the experiment at Garcia Bend was the successful retention of the material placed over the cobble rock. A good sod was formed prior to the December flood and as of this date, all three species (kikuyu grass, creeping wildrye, and coastal bermuda) are surviving. The berm slope was subjected to erosive forces for varying periods of time, especially as the flood receded. Spots of erosion occurred, mostly in the creeping wildrye plot. Deposition was not found on the slope.

The experiment at Hood was completely lost as a result of the December flood. The area wasn't seeded until October 16, 1964, and the grasses never had a chance to establish a good root system before the flood.

Placement of Revetment Around Trees

The cobble rock placed around the bases of the trees at Garcia Bend is controlling erosion where a stable slope was provided for the rock. On slopes steeper than 2:1, the rock rolls away and the tree roots are soon exposed.

Erosion Control with Vegetation

The two beach areas at Garcia Bend planted in kikuyu grass in July 1963 are now gone. Erosion started immediately after the areas were resloped and planted, resulting in vertical banks which continually degraded because of undercutting. The flood of December 1964 accelerated this action and, at one of the areas, approximately 30 feet of berm area has been lost since July 1963. This area is immediately downstream from a wing dam which causes very high velocities at the bank. The other area has lost 10 feet in spots since July 1963. Both areas are obviously subjected to extreme degradation and erosion cannot be controlled with vegetation. In such places, rock protection is necessary.

Plant Adaptation

The December 1964 flood subjected a high percentage of the test plants to prolonged inundation and considerable silt and sand deposition.

In most cases, the plants survived inundation: however, deposition more than 6 inches deep eliminated all the test plants on the flat berm areas at the Garcia Bend and Ryde sites. The only plantings at Garcia Bend exhibiting any ability to come through sand and silt up to 6 inches deep were kikuyu grass, creeping wildrye, and coastal bermuda. At Ryde, only the reed canary grass and perla grass emerged through deposition deeper than 3-4 inches.

Many of the plants on the levee slopes arrested erosion from current and wave wash very well. Kikuyu grass and coastal bermuda were superior in this respect with creeping wildrye also doing a good job. There was no visible evidence of erosion in the coastal bermuda and kikuyu grass plots at Garcia Bend. In the adjacent plots with fall plantings less than 100 feet away, erosion became so severe that sandbags were needed for protection during the flood.

As to adaptability for the spring plantings, kikuyu grass and coastal bermuda so far have proved superior to creeping wildrye. Alkali bulrush and periwinkle do not appear to be adaptable. The observations of adaptability are based on one year's performance, and final conclusions cannot be drawn until the end of the study.

The fall plantings at Garcia Bend and Ryde have shown little success. The plantings developed good initial stands; but without water the following summer, it appears they may not survive. This cannot be determined until the next growing season (fall 1965) for these plants.

None of the spring plantings have done well on the upper third of the levee slope. There is a very definite elevation (about 20 feet above summer water levels) at which the kikuyu grass, creeping wildrye, and coastal bermuda have dried out this summer.

Weed control is a constant problem, both in preparing a seedbed for the test plots and in getting the test plants established the first year. Many applications of herbicides were but partially successful in ridding the area of native grasses, forbs, and shrubs. Consequently, once the test plots were planted and irrigated, the native species soon began to crowd the test plants. It was necessary to resort to pulling the weeds by hand. This problem could be of considerable importance in any major levee revegetation program.

Tree Planting

The trees at Ryde were also subjected to the same inundation and deposition as the adjoining grasses and legumes. They appear to have survived both inundation and deposition. However, this summer (1965) most of the trees are not doing well on the upper slopes of the levee. They have not been irrigated this year. As expected, most are thriving on the berm area.

Experimental Bank Slope Protection

Many problems were encountered in placing the concrete blocks, especially in the lower tidal zone. The biggest problem was maintaining a uniform slope until the blocks were placed.

The blocks were placed from an elevation above higher high water to below lower low water and, of course, much of the work had to be done in the "wet".

After two attempts, the blocks were finally set on a fairly uniform slope. Soon after placement, two spots began to cave badly and the continuity of the mat was broken.

Vegetation on Levee Slopes

Many levees in the Delta have trees more than 20 years old that have not posed any problems or endangered the integrity of the levees. These trees have good, strong root systems and have not been undermined by erosion.

Dense growths of high-growing plants on levee slopes are also found in the Delta but are not compatible with flood control requirements. It is practically impossible to inspect levees containing dense growths of blackberry and grape vines or clumps of low-growing shrubs. Annual inspection is of paramount importance, and growth that prevents inspection is not acceptable.

Ground Cover on Berms

Ground cover on the level portions of berms is not critical to preserving and maintaining the integrity of the levee. Most berms in the Delta are subjected to frequent flooding, and selected vegetation, especially grasses, probably would have to be replanted often because of sedimentation.

Conclusions

On the basis of the tests and observations to date, the following tentative conclusions are drawn.

1. The ground cover plants tested can tolerate at least 30 days of inundation.

2. None of the ground cover plants tested will survive more than 6 inches of deposition.

3. Plants which form good solid ground cover can virtually eliminate erosion on the upper levee slopes during floods.

4. Of the ground cover plants tested, kikuyu grass, coastal bermuda, and creeping wildrye are superior in terms of being able to survive without summer irrigation and providing erosion control.

5. The fall ground cover plantings tested do not appear to be able to survive without irrigation the following summer.

6. Competition from indigenous plants requires a rigorous, selective weeding program during the initial year of establishment of the ground cover plants tested.

7. Even the superior ground cover plants (kikuyu grass, coastal bermuda, and creeping wildrye) do not grow well on the upper 1/3 of the levee slope, probably because of the lack of moisture in the summer.

8. Fill material, placed over revetment and then planted to ground cover, can be successfully retained above normal water levels.

9. Erosion control at normal water levels is essential, and control with vegetation is very doubtful at areas of degradation.

10. Almost all species of trees in the Ryde adaptation series survived inundation and deposition on the berm, but most of the trees cannot tolerate the droughty, upper levee slopes without water, at least while they are young.

11. Trees with open spacing can be retained on levees with wide sections if root exposure and top heaviness is prevented.

12. Native vegetation can be allowed to flourish on berm areas.

13. Native species of ground cover can help to control erosion with proper encouragement.

14. Studies will be required following the Pilot Levee Maintenance Study to develop specific proposals for multiple-purpose levee maintenance projects using recommendations for vegetation management.

Recommendations

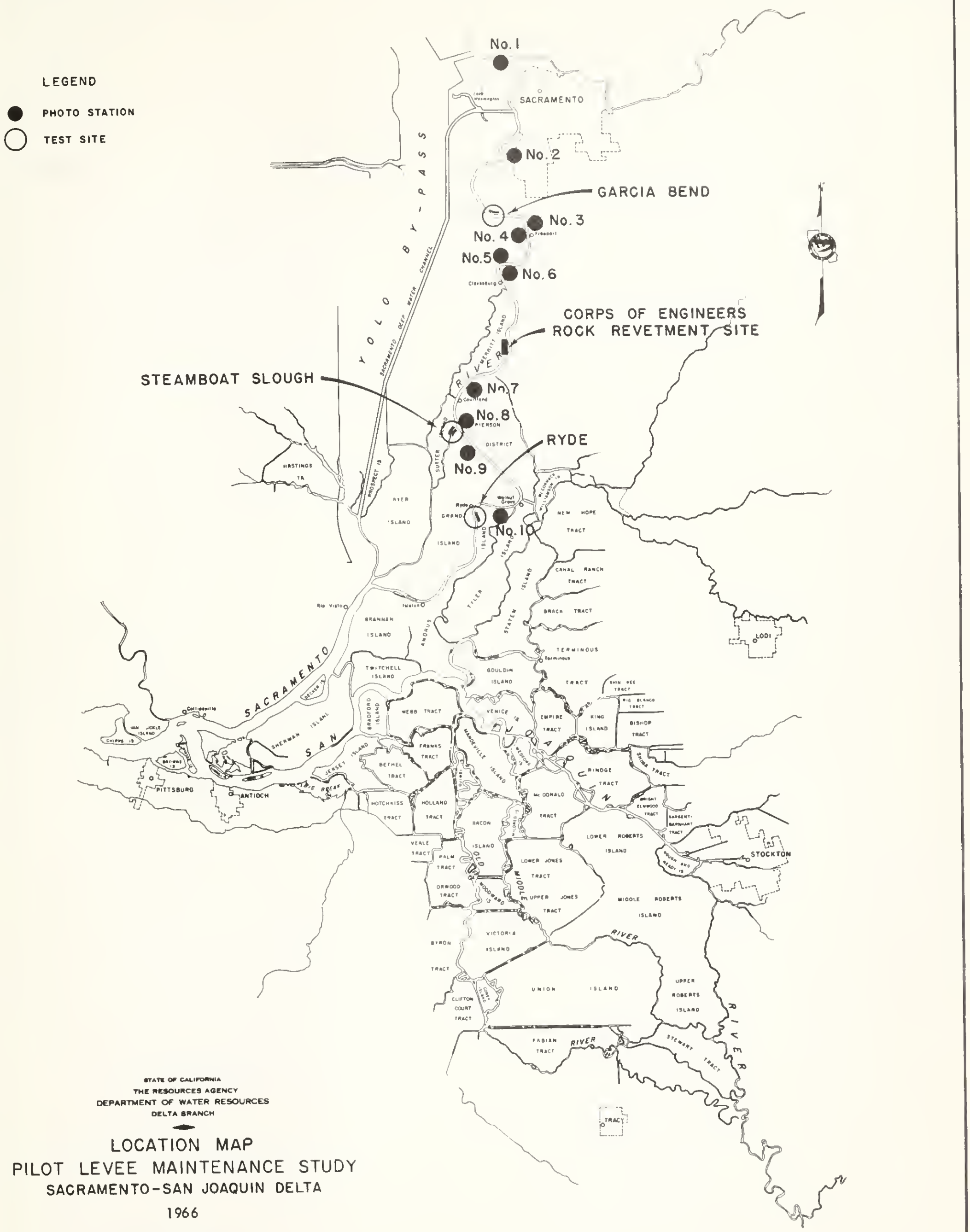
It is recommended that the scope of present levee maintenance work of concerned agencies be expanded to include vegetation management for recreation and wildlife as well as flood control. The conclusions listed in this report strongly suggest that vegetation management on levees with consideration of the requirements of all three functions can benefit flood control as well as recreation and wildlife.

The final recommendations of the Pilot Levee Maintenance Study in 1967 will set forth the guidelines for a vegetative management program. These recommendations will spell out the types, densities, and positions of grasses, shrubs, and trees for use on levees and berms and suggested maintenance practices to achieve full value for all three purposes.

It is further recommended that concerned agencies involved in and responsible for levee maintenance take immediate steps to gain authorization for and to implement prototype multiple-purpose levee maintenance programs to follow the Pilot Levee Maintenance Study. The objective of this program would be to determine the physical life of new techniques and to develop specific proposals for multiple purpose levee maintenance projects using the Pilot Levee Maintenance Study's final recommendations. These proposals should include economic justification and financial feasibility.

GLOSSARY OF SCIENTIFIC NAMES OF PLANTS USED IN THE PLANT ADAPTATION SERIES

Common Name	Botanical Name
Forbs	
Alkali bulrush	Scirpus robustus
Aarons beard	Hypericum calycinum
Boardfruited bur reed	Sparganium eurycarpum
Matgrass	Lippia nodiflora
Periwinkle	Vinca major
Spikerush	Heleocharis palustris
Grasses	
Alkar wheatgrass	Agropyron elongatum
Coastal bermuda	Cynodon dactylon
Creeping wildrye	Elymus triticoides
Goars fescue	Festuca arundinacea aspera
Greenar wheatgrass	Agropyron intermedium
Kikuyu grass	Pennisetum clandestinum
Perla grass	Phalaris tuberosa hirtiglumis
Pygmy bamboo	Bambusa pygmaea
Reed canary grass	Phalaris arundinacea
Saltgrass	Distichlis species
Tifgreen hybrid bermuda	Cynodon dactylon
Tifway hybrid bermuda	Cynodon dactylon
Topar wheatgrass	Agropyron trichophorum
Western wheatgrass	Agropyron smithii
Legumes	
Los Banos trefoil	Lotus tenuis
Salina clover	Trifolium fragiferum
Trees	
Red iron bark	Eucalyptus siaeroxylon rosea
Water wattle	Acacia retinodes
Beefwood	Casuarina stricta
Common olive	Olea europaea
Hollyleaf cherry	Prunus ilicifolia
Athel	Tamarix articulata
Trident maple	Acer buergerianum
Arizona ash	Fraxinus velutina
Black mulberry	Morus nigra
Purple plum	Prunus cerasifera var. pissardi



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

LOCATION MAP
PILOT LEVEE MAINTENANCE STUDY
SACRAMENTO-SAN JOAQUIN DELTA
1966

SCALE OF MILES